Process Specification for the Heat Treatment of Nickel Alloys

Engineering Directorate

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Prepared by: ***Signature on file*** ***8/10/09***
John D. Figert, Date
Materials & Processes
Branch /ES4

Approved by: ***Signature on file*** ***8/10/09***
Brad S. Files, Date
Chief, Materials &
Processes Branch /ES4

REVISIONS		
VERSION	CHANGES	DATE
Baseline	Original version	5/96
A	Expanded sec. 3.0, furnace chart info., tensile requirements	5/27/98
B	Changed Training Requirements	7/21/99
C	Modified Training Requirements, Labeling Tensile Bars & Stock	2/24/00
D	Included Information on Postweld Heat Treatment, Reduced Labeling Tensile Bars & Stock Requirements	8/24/00

E	Updated document due to reorganization from EM2 to ES4	1/20/04
F	Reviewed for accuracy and updated author.	10/04/06
G	Clarified the Usage statement	8/10/09

1.0 SCOPE

This process specification establishes the engineering requirements for the heat treatment of nickel and cobalt alloys.

2.0 APPLICABILITY

This specification shall be applicable whenever the heat treatment of nickel or cobalt alloys is invoked per section 3.0, “Usage”.

3.0 USAGE

The material to be heat treated shall be listed on the drawing in the heat treat condition in which the material is to be procured. Availability of product forms and tempers may be obtained from the manufacturing production controller or from the ES4 materials engineer.

This process specification shall be called out on the engineering drawing by using an appropriate drawing note. The specific process or combination of heat treat processes shall be noted, along with the final temper. For example:

AGE HARDEN TO S1750SDP PER NASA/JSC PRC-2003.

or

AGE HARDEN PER NASA/JSC PRC-2003.

or

ANNEAL PER NASA/JSC PRC-2003.

A description of the names for various heat treatments (e.g. S1750SDP) and the heat treat temperatures may be found in AMS 2774.

3.1 PROCESS SEQUENCE

Unless otherwise specified on the engineering drawing, all parts shall be heat treated before final machining to eliminate effects of oxidation, alloy depletion, de-carburization, dimensional changes, and to avoid placement of hardness impressions on the final surface. Scale that is produced when nickel and cobalt alloys are heat treated above 1550°F cannot normally be removed by mechanical or chemical finishing techniques. After heat treatment, a minimum of 0.010” will be removed during the final machining.

In some cases, it may be necessary to heat treat after final machining. If heat treating will result in a heat tinted surface that will not be removed by final machining, an appropriate finishing procedure to remove the heat tint shall be called out on the engineering drawing. For example:

HEAT TREAT AFTER FINAL MACHINING. REMOVE HEAT TINT BY ELECTROPOLISHING PER NASA/JSC PRC-5009.

Most postweld heat treat operations, when required, on nickel-based and cobalt-based alloys are generally anneals or anneals plus aging. A qualified welding procedure for the specific application needs to be reviewed before making the postweld heat treat note. For example:

AFTER WELDING, ANNEAL AND AGE HARDEN TO S1750SDP PER NASA/JSC PRC-2003.

3.2 NOTATIONS RELATED TO HARDNESS TESTS

Normally, verification of heat treatment of nickel and cobalt alloys is achieved by measuring hardness. When the hardness impressions are to be made on the actual part, a site is chosen by the designer and ES4 materials engineer that will not be detrimental to the function of the finished part. Special instructions must be included on the engineering drawing, such as:

HARDNESS TEST SHALL BE PERFORMED ON ACTUAL PART IN LOCATION SPECIFIED.

Sample parts may be used to verify heat treat instead of the actual part. Sample parts shall be sketched and/or described on the engineering drawing. They may have a simplified contour and may use nominal dimensioning. Sample parts shall be made from the same raw material lot and processed before heat treatment in an identical manner as the production parts. When the heat treating process includes quenching, the samples must be of similar thickness and mass as the production parts or shall be parted from production parts after quenching. When a hardness test is to be performed on a sample part, the following notation should be included on the engineering drawing:

HARDNESS TEST SHALL BE PERFORMED ON SAMPLE PART.

3.3 NOTATIONS RELATED TO TENSILE TESTS

For more critical parts, tensile testing may be warranted. Sample pieces for tensile coupons shall be machined from the same raw material lot and processed before heat treatment in an identical manner as the production parts. When tensile testing is required, the number of coupons, grain direction, and any special acceptance criteria shall be noted on the drawing. For example:

TENSILE TESTING IS REQUIRED AND SHALL BE PERFORMED ON SAMPLE PART(S). SAMPLE PARTS SHALL CONSIST OF THREE 6" LENGTHS OF THE SAME LOT OF MATERIAL USED FOR PRODUCTION PARTS.

4.0 REFERENCES

All documents listed are assumed to be the current revision unless a specific revision is listed.

AMS 2774	Society of Automotive Engineers Aerospace Materials Specification, *Heat Treatment, Wrought Nickel Alloy and Cobalt Alloy Parts*
ASTM E8	American Society for Testing and Materials Specification, *Standard Test Methods of Tension Testing of Metallic Materials*

ASTM E18	American Society for Testing and Materials Specification, *Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*
MMPDS	Handbook, *Metallic Materials Properties Development and Standardization*
TI-2000-01	Training Instruction: Training for Heat Treat Personnel
SAE ARP 1962	Training and Approval of Heat-Treating Personnel

The following references were used in developing this process specification:

SOP-007.1	Preparation and Revision of Process Specifications
JSC 8500C	Engineering Drawing System Requirements

5.0 MATERIALS REQUIREMENTS

None identified.

6.0 PROCESS REQUIREMENTS

All heat treatment of nickel and cobalt alloys shall comply with the drawing requirements and AMS 2774, with the following modifications:

Alloy	Spec	Heat Treat Variation	Acceptance Change
MP35N	AMS 5844	Use 1100°F precipitation set temperature.	Precipitation heat treat shall be verified by tensile testing.
MP159	AMS 5842	Use 1225°F precipitation set temperature.	No change.
Alloy 718 Bar S1750SDP	AMS 5662 AMS 5596 AMS 5889	Use 100°F per hour cool instead of furnace cool during precipitation heat treatment.	Use 36 HRC instead of 331 HB.

Alloy 718 Bar S1950DP	AMS 5664 AMS 5597	No change. No change.	Use 38 HRC instead of 341 HB.

Sample parts (e.g. for hardness and tensile measurements) shall be processed before heat treatment in an identical manner as the production parts. Sample parts must be heat treated simultaneously with the production parts. If production parts have to be processed in more than one batch, each batch must have its own set of sample bars.

Tools and equipment shall be as-specified in AMS 2774, with the following exception. If a vacuum furnace is to be used to solution heat treat nickel or cobalt alloys that require air cooling or rapid air cooling, it shall be equipped with metal elements, metal shields and an argon quench system capable of rapidly cooling parts from the annealing temperature to below 1200°F.

Safety precautions and warning notes shall be as-specified in AMS 2774.

7.0 PROCESS QUALIFICATION

Not required. However, work instructions shall be generated for implementing this process specification. The work instructions shall contain sufficient detail to ensure that the manufacturing process produces consistent, repeatable products that comply with this specification.

8.0 PROCESS VERIFICATION

Verification of furnace temperatures shall be accomplished by recording the furnace temperatures on strip charts or other suitable hard copy recordings. Furnace charts for heat treatment shall be maintained with the hardware's work order router package.

Verification of nickel and cobalt alloy heat treatment is normally achieved by measuring hardness. Hardness impressions shall be made per ASTM E18 on the actual part at the location specified on the engineering drawing or on the samples heat treated together with the part.

When tensile tests are required on the drawing, specimens shall be machined according to ASTM E8, using full-sized coupons whenever possible. Testing shall be performed according to ASTM E8 by either the JSC Structures Test Laboratory or an accredited mechanical testing laboratory. Tensile test results for nickel and cobalt alloys shall meet the minimum values listed in MMPDS. If

no tensile values are available in MMPDS for a specific alloy, acceptance values must be listed on the engineering drawing.

Labeling of stock material prior to the heat treatment shall include the material lot (certification #). Labeling of the stock material shall either be done by stenciling or by using stainless tags and stainless wire. Stainless tags shall be stenciled.

Tensile bars or tensile coupons shall be individually labeled immediately after manufacture. Label information shall always include material lot (certification #). If the tensile bars or tensile coupons are made prior to heat treating, the tensile bars or tensile coupons shall be labeled using austenitic stainless tags and austenitic stainless wire. If the tensile bars or tensile coupons are made after heat treating, cotton string and paper tags may be used instead of stainless tags and wire. Paper tags shall include material type, the material lot (certification #), and the work order router number.

9.0 TRAINING AND CERTIFICATION OF PERSONNEL

All heat treatment of steel and stainless steel alloys used on flight hardware shall be performed by qualified operators who have been certified according to the requirements in TI-2000-01, Training for Heat Treat Personnel. For vendors, a training program consistent with the recommended practices in SAE ARP 1962 shall be required.

10.0 DEFINITIONS

Age Harden	A heat treatment process which consists of applying a relatively low temperature for sufficient time to strengthen the alloy to the desired temper.
Air Cooling	The rate at which the parts, separated from one another sufficiently to allow free air movement, would cool to room temperature after being removed from the furnace and placed in shop air without rapid motion of the air forced over the parts by a fan or blower.
Alloy Depletion	Change in composition of an alloy near the surface when one element, typically chromium, evaporates at high temperatures, usually in a vacuum furnace.
Decarburization	The loss of carbon from the surface of an alloy as a result of heating in a medium (usually oxygen) that reacts with the carbon.

Heat Tint	A thin, tightly adhering oxide skin that forms when alloys are heat treated at low temperatures, or for a short time, in air or in a mildly oxidizing atmosphere. The color ranges from straw to light blue.
Precipitation Heat Treat	An intermediate temperature heat treat process that causes hardening and strengthening of the alloy by the precipitation of intermetallic compounds and, in some cases, carbides from supersaturated solid solutions.
Rapid Air Cooling	The rate at which the parts, separated from one another sufficiently to allow free air movement, would cool to room temperature after being removed from the furnace and placed in shop air with rapid motion of the air forced over the parts by a fan or blower.
Scale	A heavy, penetrating oxide layer that forms when alloys are heat treated at higher temperatures, or at longer times, in air or other oxidizing atmospheres.
Stress Relief	A thermal cycle to relieve residual stresses.